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Overview of SM and GF plant water-based extract phytochemical composition using FT-IR spectrum

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ABSTRACT

The composition of two water-based plants, *Selaginella myosurus* (SM) - (stems and leafs) and *Pneumatopteris pennigera* (Gully fern, GF: Fronds). These plants live, feed and reproduce in stagnant water in absence of which dries up, in which the GF & SM plants extracts were further analysed using FT – IR spectrum. The aim and objectives of this research is to examine the characteristics and properties of the SM & GF test inhibitors in terms of classification of quality of the specimen of the plant extracts and check if it attains high degree of corrosion inhibition due to the presence of phytochemical molecules contained in the prepared plant extract(s) capable of inhibiting corrosion on the carbon steel metal samples surfaces. The phytochemical properties of the plants show good as well as revealing the significance of the plant extracts as a useful raw material for industrial application in controlling metal corrosion.

Keywords: Overview, plant extracts, phytochemical, water-based plant, composition, FT – IR spectrum

1. INTRODUCTION

Corrosion continues to pose serious challenges to infrastructures causing loss in revenue and the action in most cases is attributed to microbial action (Ukpaka et al., 2021). Many industries use equipment made from carbon steel under varied conditions ranging from mild to harsh chemical environments, making their surfaces vulnerable to corrosion. Studies have proven that corrosion cannot be completely annihilated from metal surfaces because of the different environments in which metals are used. Corrosion affects very many industries in different sections of the economy and is often given a multi-dimensional assessment, ranging from economic view (loss, downtime of machinery, cost and profits) to the protection of employees and environmental safety in the event of its occurrence. Thus, corrosion is a universally present problem that continues to cause apprehension in a wide range of application in industries. Very many efforts are being made to have a long and unchallenging straightforward

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operation by making insignificant the rate of corrosion of metals used for industrial purposes (Madu et al., 2019).

Most common of all corrosion processes is corrosion in which the carrier solvent is liquid water. Water containing medium includes water, seawater and many other process streams in the industry. Water phase corrosion in the atmosphere is traceable to its moisture presence. The presence of water in the soil accounts for the water phase corrosion. Water is rarely found available in its pure state in the soil, atmosphere and industrial processes streams (El-Katori and Al-Mhyawi, 2019). But gases, salts and other contaminants are found dissolved in water. Their presence and possible dissolution make the water found in that water containing medium somewhat conductor of charges or electrons (Schweitzer, 2010).

Existence of water in these forms make water act somewhat as a conductor of electrons or electrical current. The chemical nature of this electron or electrical current conducting medium possibly assumes alkaline, neutral or acidic polarity. Exposure to a strong acid of a non-polarised metal surface of pure metal in oxidation reaction is one of the most occurring corrosion reactions. One out of numerous cases of oxidation is a better-known oxidation case of an un-protected pure iron in closed contact with HCl corrosive medium. Destructive bubbling of solution evidently clear is the consequential chemical reaction evolving hydrogen as one of its products (Schweitzer, 2010).

In insufficient protection of carbon steel in service environment, these acids through process of corrosion destroys carbon steel shortly. Corrosion inhibitors are therefore essentially unavoidable in the fight to prevent acids from damaging carbon steel. Given that acids are aggressive environment for oil and gas well infrastructures, the effective way to control their corrosion attack on tubing and casing materials is to inject corrosion inhibitor which could be added to the acid solution in the course of the acid cleaning processes (Chung et al., 2019; Chung et al., 2021). Corrosion inhibitors function mostly by partially altering the surface of the metal, e.g., carbon steel by means of adsorption of inhibitors molecules spring or emanate the formation of a protective thin layer (Umoren et al., 2018).

Ani et al., (2020) reported metals used in industries are exposed to several processes such as acid cleaning, pickling and scale removal, which leads to corrosion. Since the beginning of industrial revolution, carbon steel has been used as alloy for many structural and industrial implementation and employment possibly due to its cost effectiveness. Acid solutions are used and applied in so many industries throughout the course of acid cleaning, acid removal of coats and layer or incrustation – descaling, scraping or flushing, industrial cleaning and oil well acidizing simulation – an oil reservoir stimulation technique for increasing well productivity etc.

Acidic media necessitates in a uniform corrosion, a type of corrosion of carbon steel, e.g., medium carbon steel with pitting at areas or positions of higher concentrations of the acid in solution. These processes require a high degree of corrosion inhibition to protect the metal(s) from direct attack by corrosive media (Singh et al., 2017). The corrosion opposition of medium carbon steel put together consequential issues on both economical & safety views and outlook in numerous industries. And use of corrosion inhibitors is the distortion and often solution to weaken and alleviate carbon steel, e.g., medium carbon steel corrosion (Bhuvaneswari et al., 2020).

Bulk of familiar and popular inhibitors that afford and furnish carbon steel metal surfaces protection in its service environment when in exposure with harsh and invading environments are organic compounds that hold and accommodate hetero-atoms such as nitrogen, sulphur, phosphorous and oxygen atoms (Ukpaka et al., 2021). Metal corrosion inhibitors perform, for the most part, usually by compounding and improving carbon steel metals surfaces by means of adsorption of inhibitor molecules to follow and emerge in formation of a thin protective layer. Although, bulk of synthetic organic compounds employed and deployed as metal corrosion inhibitor are not economical & environmentally friendly are injurious to plants & animals, humans and the environment as a whole. Accordingly, the use of innocuous, benign or harmless and inexhaustible and sustainable plant resources – plants extract as metal corrosion inhibitors is at the cutting edge of this current investigative research scrutiny.

The use of inexhaustible natural products as metal corrosion inhibitors have been campaigned for because they are sustainable, easily accessible, ecologically admissible, non-polluting (in terms of waste generated in surface cleaning management) & affordable and can simply obtainable by adherence to simple extraction instruction (Umoren et al., 2018). The shell of Chinese goose berry fruit water-based extract is a plant source for different biologically active components like sucrose, maltose and folate are highly soluble in water and act as inhibiting molecules for carbon steel. The other components namely: Methyl-hexanoate, phytosterol and octadecadienoic acids are not soluble or less soluble in water and cannot be extracted from the shell of Chinese gooseberry fruit through water-based extraction process (Bahlakeh et al., 2019).

2. MATERIALS AND METHODS

Materials

The following materials were employed to perform this investigative study on corrosion inhibition of medium carbon steel metal sample – U-shaped channel carbon steel (MCS metal samples). Plants: *Selaginella Myosurus* (leaves & stems) & *Pneumatopteris Pennigera* (fronds). Solvent: Distilled water. Experimental apparatus includes: Desiccators, nose mask, hand glove, laboratory coat, plastic buckets, conical flask, measuring cylinder, glass bottles, balance, electric blender, GC-MS, FTIR & SEM devices. Other materials include ethanol, acetone, hydrochloric acid, detergent.

Identification of the Active Compounds of the Powdered Plants samples

To identify and characterize the active components and molecules of the plant extracts, powdered plants parts were sent for Gas chromatographic mass spectrometry, GC/MS. Gas chromatography/Mass Spectroscopy as a material analysis method employs gas chromatographs fitted with mass selective detectors – mass spectrometer. Gas chromatography – Mass Spectroscopy is an ideal tool used to identify unknown substances or contaminants – test samples in terms quantity and quality that are present in very low quantities. It can be used to study liquid, solid or gaseous samples. The analysis starts with gas chromatograph, where the specimen – test sample is productively evaporated into the gas state and separated into its different components using a capillary column coated with a stationary liquid or solid phase. The following method was used to identify the quantity and quality of *Pneumatopteris Pennigera*, GF & *Selaginella Myosurus*, SM using dried powdered test inhibitor sample of SM or GF plant parts. The dried powdered GF & SM plant samples for Gas Chromatography was analysed making use of Agilent 6890 gas chromatograph with 5973 mass spectroscope detectors equipped with 60m x 25mm, i.d 0.25μmm/MS DB − WAX capillary column agilent. The characterisation of different plants chemical components was completed following established standard procedure. Also, the phyto-chemical composition of each sample was identified with Agilent 6820 gas chromatograph. The mass spectrum results were translated making use of database from National Institute Standard and Technology (NIST) having over 62,000 patterns. The unknown fragmentation pattern spectra of the unknown components were contrasted with those of known components stored in NIST V. 3.2 library.

Plants used in the Preparation of the Test Inhibitor (Plant extract)

Two different plants *Selaginella myosurus* (also called Spike Mosses, SM - stems and leafs); *Pneumatopteris pennigera* (Gully fern, GF) frond was used in this research investigative study.

Figure 1 Cross Section of Raw (Fresh) *Selaginella myosurus* after washing with tap water and removing contaminants/impurities

Figure 2 Cross Section of Raw (Fresh) *Pneumatopteris Pennigera* (Gully fern) after washing with tap water and removing contaminants/impurities

***Selaginella Myosurus* (SM) Plant Extract in the Corrodent Medium**

100g mass ($M_{1,SM}$) of powdered SM plant was put into 1000cm³ (1.0dm³) of distilled water. 10.9423g of SM powdered sample completely dissolved in 1.0 litres distilled water

Table 1 SM Extract Corrodent Medium Volume/Mass Compositions – Preparation Summary

SM Plant Extract + 1.0M HCl Samples	Volume/Mass Composition (Mass Concentration SM = 10.9423g/L)		
	Dilute Acid (1.0M HCl)	SM Test Inhibitor	Corrodent Volume used
D	60% (150mls)	40% (100mls – 1.094g)	100% (250mls)
E	20% (50mls)	80% (200mls – 2.1880g)	100% (250mls)
F	40% (100mls)	60% (150mls – 1.6410g)	100% (250mls)
G	80% (200mls)	20% (50mls – 0.5470g)	100% (250mls)
I	50% (125mls)	50% (125mls – 1.3675g)	100% (250mls)
C (Control)	100%	-	100% (250mls)

Table 2 SM Extract Corrodent Medium Volume/Mass Compositions – Preparation Summary

Other volumes of the test inhibitor plant extract in concentrated HCl				
SM Extract Samples + HCl	Raw Acid (HCl) (Analytical grade)	Test Inhibitor (mls)	Distilled water (mls)	Total Corrodent Volume used
M	87.3mls	500mls (5.4711g)	500mls	100% (250mls)
O	87.3mls	1000mls (10.9423g)	-	100% (250mls)

***Pneumatopteris pennigera* (gully fern, GF) Plant Extract in the Corrodent Medium**

100g of mass ($M_{1,GF}$) of powdered GF plant was put into a sizeable plastic container to which 1000cm³ (1.0dm³) of distilled water was added. 20.19g of GF powder was found to have dissolved completely in 1.0 litres of distilled water

Table 3 GF Extract Corrodent Medium Volume/Mass Compositions – Preparation Summary

GF Extract Samples + HCl	Volume/Mass Composition (Mass Concentration = 20.191g/L)		
	Dilute Acid (1.0M HCl)	GF Test Inhibitor	Total Corrodent Volume used
A	60% (150mls)	40% (100mls – 2.0190g)	100% (250mls)
B	80% (200mls)	20% (50mls – 1.0095g)	100% (250mls)
H	40% (100mls)	60% (150mls – 3.0285g)	100% (250mls)

J	20% (50mls)	80% (200mls – 4.0380g)	100% (250mls)
K	50% (125mls)	50% (125mls – 2.5238g)	100% (250mls)
C(Control)	100%	-	100% (250mls)

Table 4 GF Extract Corrodent Medium Volume/Mass Compositions – Preparation Summary

Other volumes of the test inhibitor plant extract in concentrated HCl				
GF Extract Samples + HCl	Raw Acid (HCl) (Analytical grade)	Test Inhibitor (mls)	Distilled water (mls)	Total Corrodent Volume used
L	87.3mls	500mls (10.0958g)	500mls	100% (250mls)
N	87.3mls	1000mls (20.1915g)	-	100% (250mls)

3. RESULTS AND DISCUSSION

Plant Extracts Characterization

In the preparation of the plant extract – Table 1, 2, 3 and 4, it was found that 10.9423g of *Selaginella myosurus*, SM powder completely dissolved in 1000mls of distilled water extractive solvent hence its mass concentration measured in g/L. Similarly, 20.191g of *Pneumatopteris pennigera*, GF was also found to have completely dissolved in 1000mls in the said solvent on record implying its mass concentration. A variant from the customary route of acid dilution in the laboratory involved a direct dilution of the concentrated hydrochloric acid with 500mls plant extract plus 500mls of distilled water to make 1000mls like distilled water acid dilution or 1000mls of the water-based plant extract only was adopted to answer the question, "What if in cases where the concentrated hydrochloric acid or its dilute in higher concentrations greater than 1.0 molar concentration is required in cleaning of surfaces, pigging of pipelines or oil well stimulation?" There are two (2) water-based plants extracts. One was made from *Selaginella myosurus*, SM and the other from *Pneumatopteris pennigera*, GF. The following are their characterization results and discussion.

Gas Chromatography/Mass Spectrometry, GC/MS of the Powdered Plant Sample

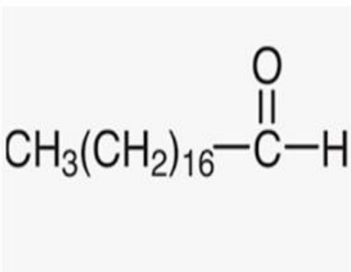
The results of gas chromatography – mass spectrometry of the two (2) plants made from dried powdered *Selaginella myosurus*, SM & *Pneumatopteris pennigera*, GF plant (Table 5, 6). Both tables are a quantification summary report of powdered plant samples of two (2) water – based plants – plants that live, survive and reproduce only in the presence of stagnant water.

Table 5 is a GCMS technique phytochemical quantification summary report of *Pneumatopteris pennigera*, Gully Fern – GF prepared powdered sample is majorly composed of Octadecanoic acid (over 42.5%) followed by hexadecanoic acid (over 35.8%), methyl stearate (over 8.4%), oleic acid (over 1.23%). This therefore shows and proves that prepared gully fern powdered sample contain carboxylic acid (-noics), adehyde (-nals) and esters (-noates) with complete absence of alkenes (-ene). Table 6 shows the phytochemical composition of prepared powdered sample of *Selaginella Myosurus* as identified using GCMS technique. It can be seen very clearly that *Selaginella Myosurus*, SM contain esters (-oates), aldehydes (-nals), alkenes (-ene), alcohol (-ols). Prepared powdered sample SM plant has highest area percentage in octadecanoic acid (over 54.65%) followed by hexadecanoic acid (over 37.61%) with complete absence of oleic acid as contained in *Pneumatopteris Pennigera*. Past work on green inhibitor have established molecular phytochemicals components capability in corrosion rate inhibition of metal samples in contact with corrosive environments. Extensive literature review, research have shown that these molecules and hence functional group are capable of inhibiting the rate at which corrosion takes place on metal surfaces in acidic and other media where the use of metals and other substances that rust or corrode are inevitable (Umoren et al., 2015).

Figure 3 is a representation of the structural & molecular formula of likely molecules and associated functional groups contained in the distilled water solvent extract of *Selaginella myosurus* and *Pneumatopteris pennigera*, GF plant. For example, -OH, -COOH, -COOR', -CO, etc.

Table 5 Summary of Phytochemical Quantification Report of Powdered Spike Moss Sample

Header=	PK	RT	Area Pct	Library/ID (SM Powdered Sample Composition)	Ref	CAS	Qual
1=	1	6.8056	0.1239	Tridecane	51391	000629-50-5	64
2=	2	15.1436	0.1949	Undecanoic acid, 10-methyl-, methyl ester	78103	005129-56-6	93
3=	3	19.9672	0.8476	Methyl tetradecanoate	104287	000124-10-7	98
4=	4	23.9228	0.2842	cis-13-Octadecenoic acid	142083	013126-39-1	60
5=	5	24.5195	37.612	Hexadecanoic acid, methyl ester	130813	000112-39-0	99
6=	6	25.9479	0.0968	3-Eicosene, (E)-	140277	074685-33-9	70
7=	7	28.0294	54.6549	9-Octadecenoic acid (Z)-, methyl ester	155750	000112-62-9	99
8=	8	28.5041	3.4381	Heptadecanoic acid, 16-methyl-, methyl ester	157955	005129-61-3	98
9=	9	31.6691	0.5509	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	210562	000111-03-5	59
10=	10	32.154	0.2234	14-Octadecenoic acid, methyl ester	155733	056554-48-4	64
11=	11	33.944	0.7867	E-9-Hexadecenal	100552	1000130-90-3	86
12=	12	34.7941	0.7165	E-9-Hexadecenal	100552	1000130-90-3	74
13=	13	35.0938	0.4254	E-9-Hexadecenal	100552	1000130-90-3	78
14=	14	35.4792	0.2686	9,12-Octadecadien-1-ol, (Z,Z)-	126846	000506-43-4	74
15=	15	35.9168	0.5405	1-Docosene	167462	001599-67-3	91
16=	16	36.169	0.333	Tetradecanal	76509	000124-25-4	86
17=	17	36.9519	0.0849	1-Tricosene	180802	018835-32-0	91
18=	18	37.8093	1.1823	Octadecanal	128800	000638-66-4	91



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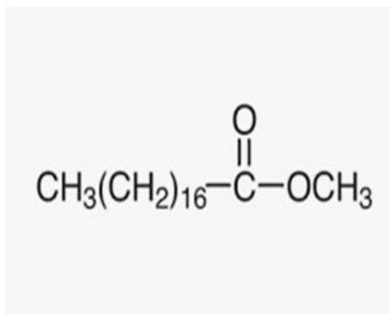

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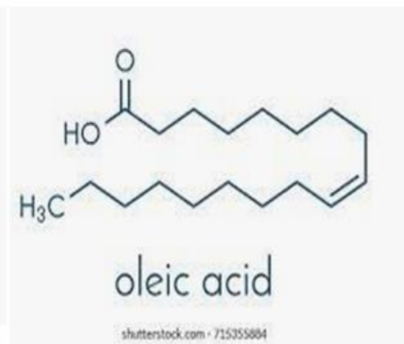

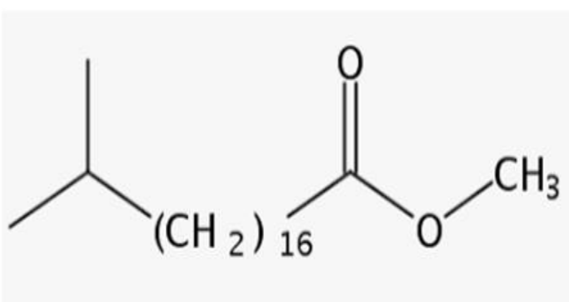

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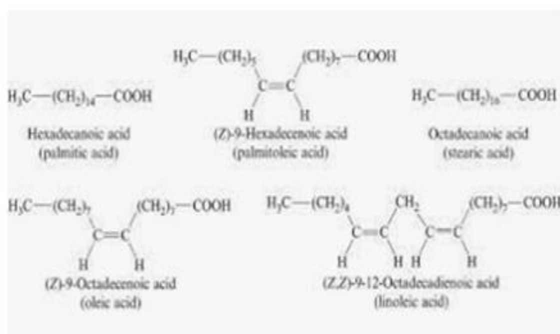

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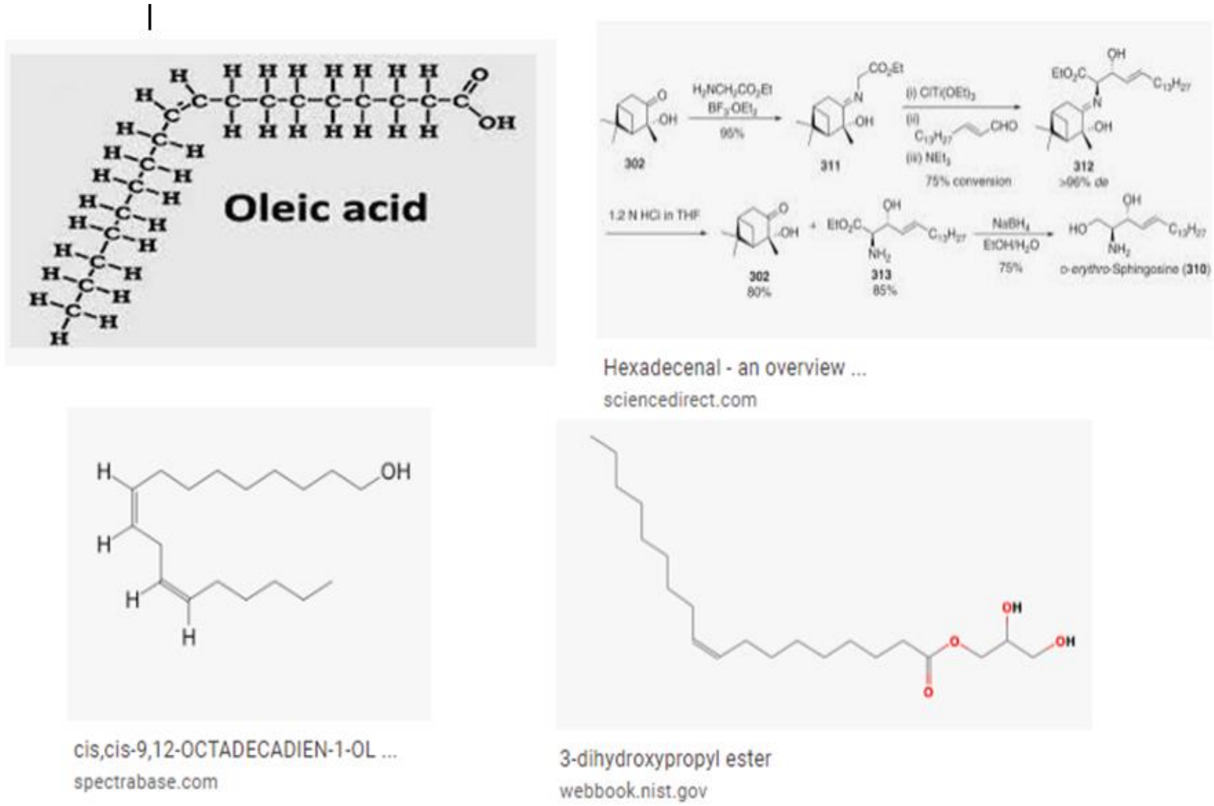


Figure 3 Structure of some molecules phytochemical components contained in the SM & GF plant powdered samples of GC-MS technique analysis results

Fourier Transform Infrared Spectroscopy

Figure 4 and 5 are the spectra that resulted from the characterization of distilled water-soluble components contained in the prepared GF or SM plant extract using Fourier transform infrared technique. This clearly shows the infrared spectrum of GF & SM plant extract. Also, the spectra peaks, compound class and functional groups of the extracts were determined based on the interpretation of the FT-IR spectrum of extracts using standard chart. Thus, the results of the absorption (peaks) revealed the possible functional groups of the spectrum. This revealed that the extracts contain compounds such as carboxylic acid, esters, aldehydes, aliphatics, amines, aromatics and phenol.

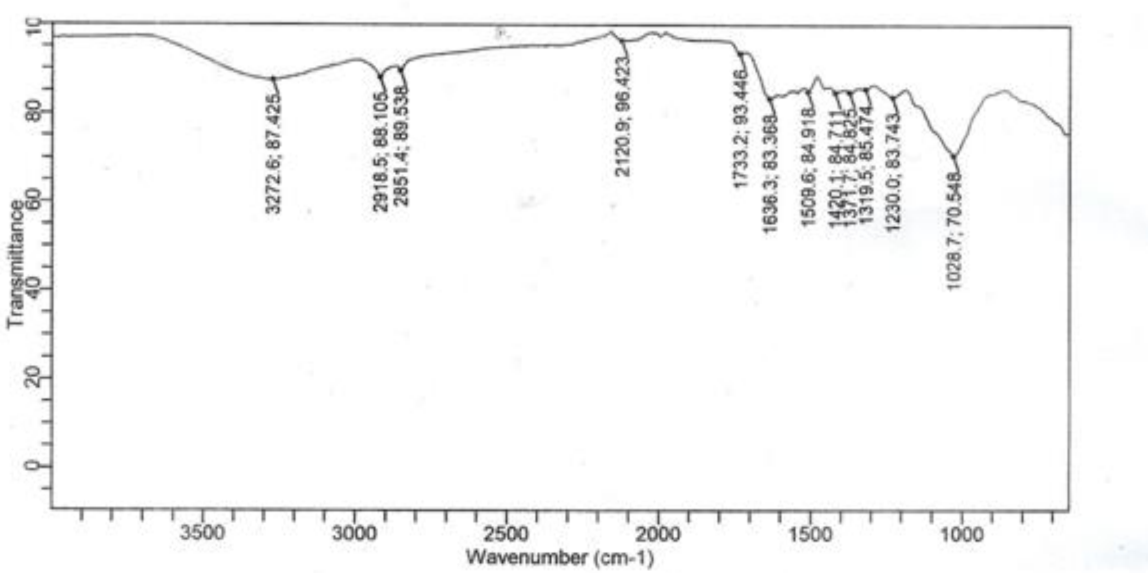


Figure 4 FT-IR Spectrum of SM Plant Water based Extract phytochemical composition

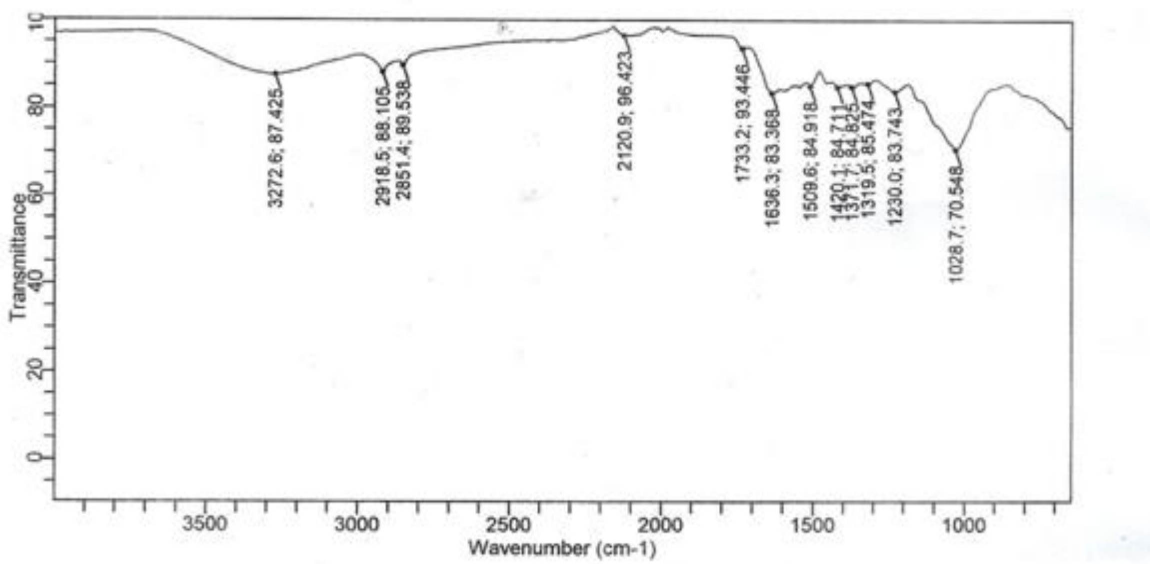


Figure 5 FT-IR Spectrum of SM Plant Water based Extract phytochemical composition

Heteroatoms like oxygen, nitrogen, sulphur and double or multiple bonds are contained in these compounds. Thus, these deductions are in accordance with previous study of El-Nemr et al., (2014) and Verma et al., (2018) etc that recognizes the presence of these compounds and others in crude extracts to inhibit the rate of corrosion of metals in an acidic or salty (corrosive) environment. Ogunleye et al., (2020) on FT-IR analysis reported that the existence of phytochemical molecular compositions having nitrogen- and/or oxygen- that is, hydroxy aromatic compound, for example, tannins, flavonoids, pectins, etc. including components of green nature origin in extract hence confirmed the extract metal corrosion inhibitor.

Furthermore, the FT-IR characterization of the test inhibitors showed all the peaks and different wave numbers of molecules contained. The peaks were used to identify the possible functional groups of the compounds in the crude extracts. The results of the characterization of the test inhibitor extract using FT-IR (Table 6); while the FT-IR spectra, compound class, functional group and appearance for each plant extract are highlighted (Table 6, 7).

Table 6 FT-IR Analysis Results showing Functional Groups in the SM Plant Extract

SM FT-IR Spectra Peaks	Compound Class	Functional Group	Appearance
1028.74524	None	-	-
1230.02149	Amine	C-N stretching	Medium
1319.47759	Phenol	O-H bending	Medium
1371.66032	Sulfonate	S=O stretching	Strong
1420.11572	Carboxylic acid	O-H bending	Medium
1509.57182	Nitro compound	N-O stretching	Strong
1636.30131	Alkane	C=C stretching	Medium
1733.21209	Aldehyde	C=O stretching	Strong
2120.85523	Carbodiimide	N=C=N stretching	Strong
2851.41345	Amine salt	N-H stretching	Strong, broad
2918.50553	Alkane	C-H stretching	Medium
3272.60262	Alkyne	C-H stretching	Strong, sharp

Table 7 FT-IR Analysis Results showing Functional Groups in the SM Plant Extract

SM FT-IR Spectra Peaks	Compound Class	Functional Group	Appearance
1028.74524	None	-	-
1230.02149	Amine	C-N stretching	Medium
1319.47759	Phenol	O-H bending	Medium
1371.66032	Sulfonate	S=O stretching	Strong
1420.11572	Carboxylic acid	O-H bending	Medium
1509.57182	Nitro compound	N-O stretching	Strong
1636.30131	Alkane	C=C stretching	Medium
1733.21209	Aldehyde	C=O stretching	Strong
2120.85523	Carbodiimide	N=C=N stretching	Strong
2851.41345	Amine salt	N-H stretching	Strong, broad
2918.50553	Alkane	C-H stretching	Medium
3272.60262	Alkyne	C-H stretching	Strong, sharp

FTIR Metal Surface Analysis

Figure 6 shows the FT-IR spectra of the medium carbon steel after 9.00hrs of suspended immersion incubation, the thin film on the medium carbon steel sample in *Pneumatopteris Pennigera*, GF plant extract/1.0M HCl solution corrodent medium, only two components were identified by the FT-IR device. This implies that some components physically adsorbed (physisorption) to form a protective film on the surface of the MCS metal samples. That is to say that some of the adsorption occurred by physisorption. Presence of these components blocked the active site for corrosion thus protecting the metal from deterioration due to its presence in dilute hydrochloric acid environments.

Gravimetric results and SEM analyses prove that adsorption occurred spontaneously on the surfaces of carbon steel metals samples contained in the corrodent medium with GF or SM plant extract. From Figure 6, the FT-IR spectrum of 9.0hrs suspended immersion incubation of medium carbon surfaces in SM corrodent medium. The FT-IR device could not identify any component in the thin film on the surface of the medium carbon steel sample. This quickly implies that the adsorption occurred through chemisorption rather than physisorption.

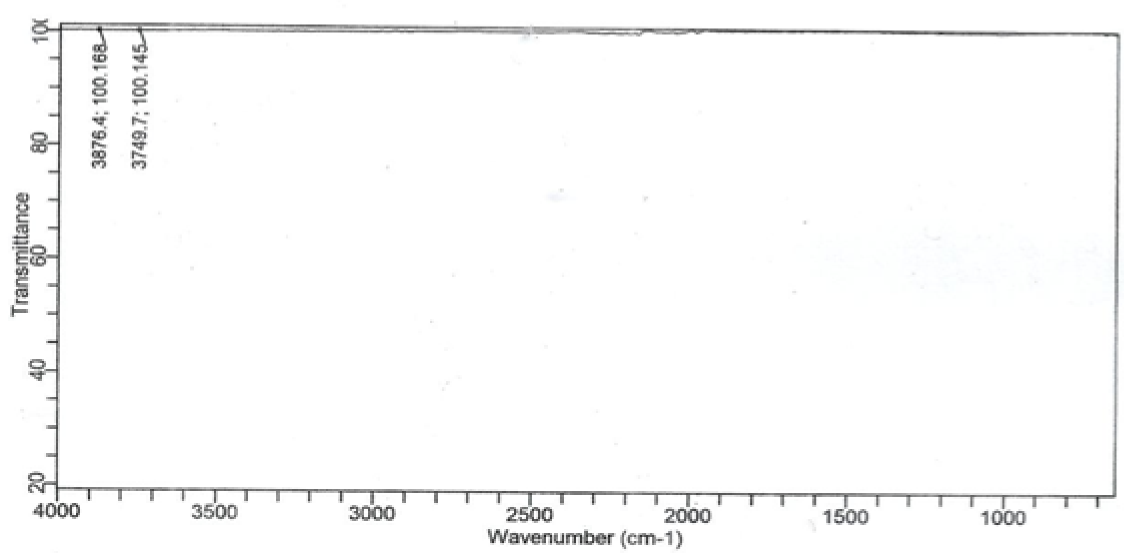


Figure 6 FT-IR spectrum of GF Plant Extract Molecules on the Surface of the Carbon Steel

SEM Microstructure Analysis – Surface Morphology of Medium Carbon Steel Metal Sample

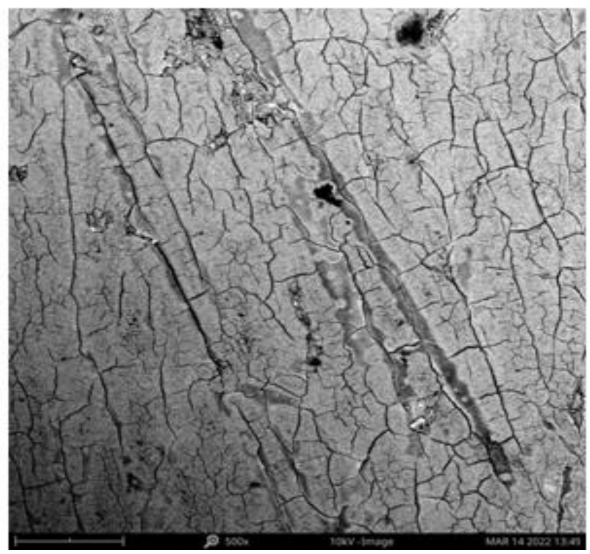
The test inhibitors are referred to as *Seleginella myosurus* or *Pneumatopteris pennigera*. Scanning Electron Microscopy (SEM) microstructure surface examination technique was used for surface characterization of the MCS metal sample before and after

immersion for 9.00hrs at room temperature in a solution of 1.0M HCl as corrodent solution at maximum (80%), minimum (20%) volume concentrations of SM or GF plant extract and in complete absence of the test inhibitors – Control/Blank C are presented in Figure 7(a-f). A fresh medium carbon steel metal sample surface was also characterised and its result was used as a standard to compare, contrast and compute damage extent induced by dilute hydrochloric acid in the corrodent mixture. These results show that in a complete absence of the test inhibitors in the corrodent mixture, 1.0 molar concentration dilute hydrochloric acid, the medium carbon steel surface was seriously battered and damaged as hole, pits and cracks are very visible (Figure 7b).

The extent of the damage was progressively dependent on the volume of the test inhibitors in the corrodent medium (Figure 7c-f). This battered surface could be attributed to the metal samples dissolution in the hash acidic environment of 1.0M HCl. Pits and cracks in their myriad of numbers were very visible, even by visual inspection. Using the former (Figure 7a, 7b) as a frame of reference to compare with the later (Figure 7c-f), it is visible from the SEM microstructure surface photographs that the presence of GF & SM prepared plant extracts reduced damages on the surfaces of medium carbon steel in aggressive acidic, hydrochloric acid corrosive medium with the test inhibitors.

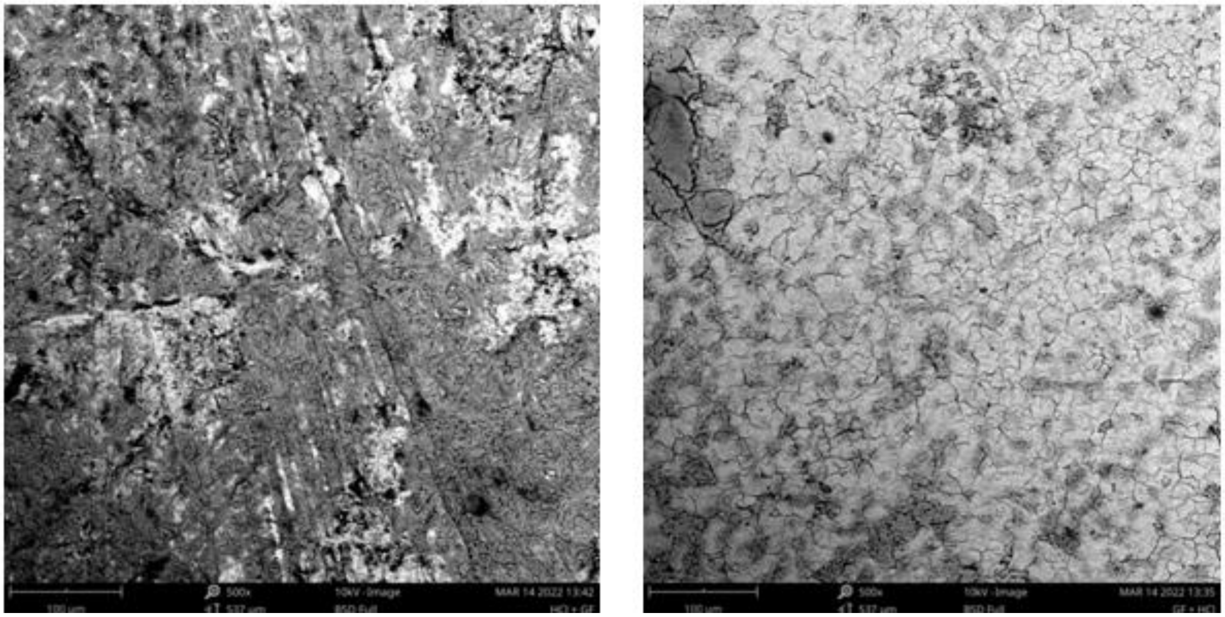
The possible reason for the later observation is the formation of protective layer/film on the surfaces of the medium carbon steel metal samples. That is, the adsorbed layer of inhibitor isolates the metal surface from the surrounding hydrochloric acid corrosive medium by forming a barrier between metal/corrodent solution interfaces and hence mitigates the corrosion (Chung et al., 2019). From the SEM microstructure surface photographs (Figure 7c, 7f), it's very clear that the medium containing GF plant extract had less pits and cracks hence less damage(s) on the medium carbon steel metal samples than samples from SM plant extract containing medium (Figure 7e).

7a



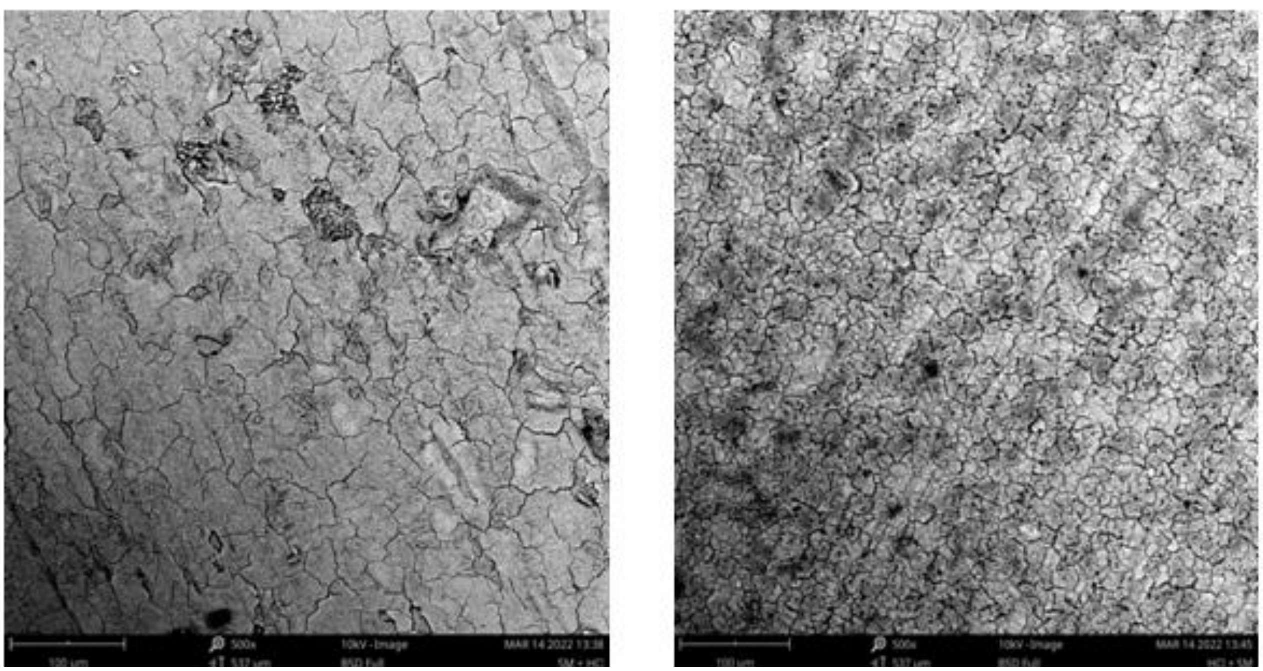
7b

Figure 7a and 7b 7a: SEM Microstructure Surface Photograph of Fresh Medium Carbon Steel Metal Sample; 7b: SEM Microstructure Surface Photograph of Medium Carbon Steel Metal Sample immersed in 100% 1.0M HCl Corrodent Medium



7c 7d

Figure 7c and 7d 7c: SEM Microstructure Surface Photograph of Medium Carbon Steel Sample in 20% 1.0M HCl + 80% GF Plant ExtractFigure; 7d: SEM Microstructure Surface Photograph of Medium Carbon Steel Metal Sample in 20% 1.0M HCl + 80% SM Plant Extract



7e 7f

Figure 7e and 7f 7e: SEM Microstructure Surface Photograph of Medium Carbon Steel Metal Sample in 80% 1.0M HCl + 20% SM Plant Extract Corrodent Medium; Figure 5f: SEM Microstructure Surface Photograph of Medium Carbon Steel Metal Sample in 80% 1.0M HCl + 20% GF Plant Extract Corrodent Medium

4. CONCLUSION

The two plants sampled are found useful as corrosion inhibitor on metal material as demonstrated from the result obtained from the phytochemical result in terms of composition as well as using plant extract in a corrosive environment reduces metal corrosion as it forms a thin film due to adsorption of phytochemicals contained in the prepared plant extract. Although depending on the acid concentration, temperature or percentage concentration of the dilute acid in the corrodent medium an undulating profile often

emanates. This is due to unrelenting struggle of the corrosive environment in breaking the protective layer formed by the phytochemical molecules of the test inhibitor having the affinity and required amount of energy to adsorb on the surfaces of metal samples. Prepared water-based plants: *Selaginella Myosurus* and *Pneumatopteris Pennigera* extract was used as the test inhibitor in hydrochloric acid medium as the corrosive agent in which medium carbon steel samples were wholly and completely incubated for a known period of time in the presence of air. The following conclusions were drawn as a result of strict adherence to the objectives of the study which helped to actualise the aim of the investigative study. SEM morphology studies results by visual inspection of SEM photographs shows SM or GF at higher volumes than the dilute hydrochloric acid in the corrodent medium reduced pits and cracks significantly, especially GF plant extract on the carbon steel samples. Hence reduction in the rate of corrosion reaction on the medium carbon steel metal samples surfaces immersed in the corrodent mixture. SEM morphological photograph of GF plant extract inhibited the rate of corrosion of MCS metal samples more than SM plant extract. All extracts were made using distilled water as solvent.

Informed consent

Not applicable.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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